

Remarks

Acceptance/formal entry therefor of this Amendment as a supplement to the recently filed fully responsive amendment, dated June 14, 2004, is respectfully requested.

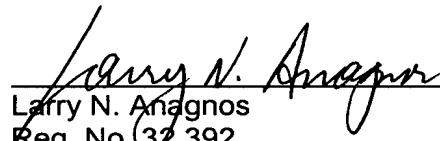
With regard to the claims, the changes being implemented therein are to correct grammatical informalities including to maintain consistency of the expressions used throughout the body of the claim. With regard to the currently amended independent claim 4, the expression "said two fuel spay holes," which relates to language originally used in the corresponding base claim 1 and which was incorporated into that of claim 4 with regard to the responsive amendment of June 14, 2004, has now been appropriately revised to the expression "said two fuel injection holes", which conforms more closely to the related set forth expression "two fuel injection holes" in the claim. Incidentally, the Examiner was correct to note that the term *spray* was incorrectly spelled in the originally existing expression aid two fuel spay holes". Any previously existing informality directed thereto, it is submitted, has now been rendered moot. Regarding dependent claim 10, two (2) minor grammatical corrections are being implemented therein.

Minor editorially clarifying/corrective revisions are also being implemented in the Specification including to remove discovered informalities therein. Due to the extensiveness of the revisions being implemented, however, applicants are submitting herewith a Substitute Specification as **Attachment A** along with a marked-up version of the original Specification, enclosed herewith as **Attachment B**. It is submitted, new matter was not added with regard to the Substitute Specification, either by addition and/or deletion.

Reconsideration as well as favorable action on the above-identified application in consideration of the recently filed fully-responsive amendment, dated June 14, 2004, as supplemented with this present filing is respectfully requested.

Please charge any shortage in the fees due in connection with the filing of this paper to the Deposit Account of Antonelli, Terry, Stout & Kraus, LLP, Dep. Acct. No. 01-2135 (503.40576X00), and please credit any excess fees to such deposit account.

Respectfully submitted,
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LNA/dks
703-312-6600
Enclosures:

Attachment A (Substitute Specification)
Attachment B (Marked-up Version)

TITLE OF THE INVENTION

FUEL INJECTION VALVE AND FUEL INJECTION SYSTEM

BACKGROUND OF THE INVENTION

5 Field of the Invention

The present invention relates to a fuel injection valve, and to a technology of atomizing fuel and controlling the injecting direction.

Prior Art

10 Acceleration of atomization of fuel injected from a fuel injection valve and accurate control of the injecting direction are considered to be one of the most important problems to cope with improving fuel consumption and cleaning of exhaust gas of an internal combustion engine.

15 Japanese Patent Application Laid-Open No.61-234266 discloses a fuel injection system comprising a first main intake passage to be opened and closed by a first intake valve and a second main intake passage to be opened and closed by a second intake valve, the first main intake
20 passage and the second main intake passage being opened to one of combustion chambers of an internal combustion engine; an opening-and-closing valve arranged in a main intake passage, the opening-and-closing valve being closed during low load operation and opened during high load
25 operation; an auxiliary intake passage branched from the main intake passage at a position upstream of the opening-and-closing valve, the outlet end being opened to the first

main intake passage at a position near the first intake valve, a passage area of the auxiliary passage being smaller than an area of the main intake passage; and a fuel injection system having a first ^{injection hole} and a second injection ^{hole} arranged in the main intake passage at positions downstream of the opening-and-closing valve, an injection path of the first injection hole being oriented so as to direct ^{the injection} to the first intake valve, an injection path of the second injection hole being oriented so as to direct ^{the injection} to the second intake valve.

Further, ^{above referenced Japanese published application} the ~~gazette~~ discloses that a diffusion angle of the injection path in the second injection hole is set smaller than a diffusion angle of the injection path in the first injection hole, and an amount of fuel injection through the first injection hole is set larger than an amount of fuel injection through the second injection hole. Furthermore, in the fuel injection valve, the opening area of the both injection holes are different from each other in order to make the amounts of fuel injection from the both injection holes different from each other.

Japanese Patent Application Laid-Open No.8-218986 discloses a fuel injection system comprising a fuel injection valve for injecting fuel spray inside an intake pipe, the fuel injection valve being arranged at a position upstream side of an intake valve in the intake pipe of an internal combustion engine, wherein an injection portion of the fuel injection valve comprises at least one injection

hole having a curved nearly semi-arc shape² and³ further, the fuel injection valve is arranged so that an outermost peripheral portion of the spray is within a range of a tangent line connecting between a wall surface of an intake port and the injecting portion and may collide against an area within a back surface of the intake valve.

In the above-mentioned conventional technology, two sprays are injected from one fuel injection valve toward two directions⁵ so that each of the two sprays may be injected onto ^{a respective one} each of two intake ports provided in one combustion chamber. However, fuel atomization forming the spray at that time is not sufficiently considered.

In addition, in the case where fuel is sprayed in the two directions, the traveling time until the spray reaches the combustion chamber (hereinafter, referred to as "transport time")¹² not always ~~becomes~~¹ the same between the two sprays due to the deviation of intake flow rate and the resistance of flow passage caused by the structure and the shape of the intake passage. Otherwise, the structure and the shape of the intake passage (intake pipe) may be restricted by intending to make the transport time equal between the two sprays. In the above-mentioned conventional technology, the time lag in the traveling time until the spray reaches the combustion chamber between the two sprays (hereinafter, referred to as "transport lag") is not considered. In the ~~former~~^{Surit} of the above-mentioned two ~~Japanese published applications~~^{gazettes}, the diffusion angle of spray is made different

between the first injection hole and the second injection hole ~~but~~ ^{however, without having considered varying the} ~~it is not taken into consideration to vary~~ penetration of each spray. The penetration of spray varies depending on the degree of atomization of fuel composing the spray ^{and} ^{consequently} the penetration of spray can ^{be} not uniquely determined from an amount of fuel injection or an initial speed of injected fuel.

SUMMARY OF THE INVENTION

10 An object of the present invention is to improve atomization of fuel injected in two directions.

Another object of the present invention is to solve the problem of the time lag in the traveling time until the spray reaches the combustion chamber between the two sprays.

15 In order to improve atomization of fuel injected in the two directions, the fuel injection valve and the fuel injection system comprise the following structures.

The fuel injection valve comprises a valve seat and a valve disc arranged detachably from and attachably to said valve seat; two fuel injection holes arranged in a downstream side of the valve seat; and a swirl force adding means for adding a swirl force to fuel, the swirl force adding means being arranged in an upstream side of the fuel injection holes and in a downstream side of the valve seat corresponding to each of the fuel injection holes so that fuel may be sprayed through the two fuel ^{spray} ~~spray~~ holes toward two directions.

Therein, it is preferable that the swirl force adding means comprises a through hole penetrating from an upstream side end surface of a plate member to a downstream side end surface; and a fuel passage for introducing fuel into the through hole toward a direction offset in regard to a center of the through hole, and the swirl force adding means are formed in the plate member positioned in an upstream side of the fuel injection holes, and the swirl force adding means are juxtaposed in a surface direction of the plate member.

Further, it is preferable that the fuel injection valve comprises a first plate member having two fuel injection holes, the two fuel injection holes penetrating through the first plate member from an upstream side end surface to a downstream side end surface so as to be directed in directions different from each other, the two fuel injection holes being independently juxtaposed in a surface direction of the upstream side end surface and the downstream side end surface; and a second plate member having the two swirl force adding means, the two swirl force adding means being formed of two through holes penetrating through the second plate member from an upstream side end surface to a downstream side end surface and independently juxtaposed in a surface direction of the upstream side end surface and the downstream side end surface; and fuel passages provided in the individual through holes, the fuel passage being directed toward a

direction offset with respect to a center of the fuel passage to communicate with the fuel passage, wherein the first plate member and the second plate member are piled up in order of the first plate member and the second plate member from the downstream side of fuel flow so that the two through holes of the second plate member individually communicate with the two fuel injection holes of the first plate member.

Therein, it is preferable that the fuel injection valve further comprises a third plate member having passage wall surfaces forming fuel passages communicating from an upstream side end surface to a downstream side end surface of the third plate member, wherein the first plate member and the second plate member and the third plate member are piled up in a downstream side of the valve seat in order of the first plate member, the second plate member and the third plate member from the downstream side so that the fuel passages of the third plate member communicate with the fuel passages of the second plate member, and the two through holes of the second plate member individually communicate with the two fuel injection holes of the first plate member.

Further, in each of the structures described above, it is preferable that penetrations of fuel sprays injected from the two fuel injection holes are made different from each other by making swirl forces added to the fuel different between the two swirl force adding means. It is

possible to provide the structure of the fuel injection valve which is capable of eliminating the time lag in the traveling time until the spray injected from the fuel injection valve reaches the combustion chamber between the two sprays.

The fuel injection system comprises an intake pipe for supplying air to an internal combustion engine; an intake air flow control device for controlling an air flow flowing inside the intake pipe; and a fuel injection valve for injecting fuel, the fuel injection valve being arranged at a position downstream of the intake air flow control device inside the intake pipe, wherein the fuel injection valve comprises a valve seat and a valve disc arranged detachably from and attachably to the valve seat; two fuel injection holes arranged in a downstream side of the valve seat; and a swirl force adding means for adding a swirl force to fuel, the swirl force adding means being arranged in an upstream side of the fuel injection holes and in a downstream side of the valve seat corresponding to each of the fuel injection holes so that fuel may be sprayed through the two fuel ~~holes~~^{sprays} toward two directions.

Further, the following structures are the fuel injection valve and the fuel injection system which are capable of eliminating the time lag in the traveling time until the spray injected from the fuel injection valve reaches the combustion chamber between the two sprays.

The fuel injection valve comprises a valve seat and a

valve disc arranged detachably from and attachably to the valve seat; a fuel injection hole for injecting fuel in two directions, the fuel injection hole being arranged in a downstream side of the valve seat; and a means for making
5 penetration different between fuel sprays injected in individual directions.

Further, the fuel injection system comprises an intake pipe for supplying air to an internal combustion engine; an intake air flow control device for controlling
10 an air flow flowing inside the intake pipe; and a fuel injection valve for injecting fuel, the fuel injection valve being arranged at a position downstream of the intake air flow control device inside the intake pipe, wherein the fuel injection valve is a fuel injection valve for
15 injecting fuel in two directions, and the fuel injection valve has a means for making penetration different between fuel sprays injected in individual directions.

Further, it is preferable that the intake air flow control device described above is arranged so that air flow
20 rates supplied to the individual two fuel sprays injected from the fuel injection valve toward the two directions can be changed.

Further, it is preferable that a rotation shaft of an opening-and-closing valve of the intake air flow control
25 device and a valve stem of the fuel injection valve are arranged in parallel to each other, and the fuel injection valve injects fuel so that one fuel spray between the two

fuel sprays is directed ^{to} one side of a plane including the rotation shaft and the valve stem as a boundary, and the other fuel spray between the two fuel sprays is directed ^{to} the other side of the plane as the boundary.

Further, it is preferable that as the means for making the penetration different, ^{the} number of fuel injection small holes for forming one fuel spray is set to a different number between the two fuel spray ^s so that the penetrations of the two fuel sprays may be different from each other.

BRIEF DESCRIPTION OF DRAWINGS

~~FIGS. 1(a) and 1(b) are schematic views~~
~~FIG. 1 is a view showing an example of a fuel~~
~~in accordance with the present invention,~~
 injection system applied to an internal combustion engine.

FIG. 2 is a ^{schematic} view showing an example of a fuel ^{in accordance with the present invention,} injection system applied to an internal combustion engine. ^{of a different type}

FIG. 3 is a ^{schematic} view showing ^{another} example of a fuel ^{in accordance with the present invention,} injection system applied to an internal combustion engine.

FIG. 4 is a vertical cross-sectional view showing a ^{in accordance with the present invention} fuel injection valve.

FIG. 5 is an enlarged vertical cross-sectional view ^{of the fuel injection valve in FIG. 4} showing an injection nozzle portion.

~~FIGS. 6(a) - 6(c) are front,~~ ^{applicable to the present invention}

~~FIG. 6 is views explaining various kinds of plates.~~

~~7(a) partial front view of an injection plate and FIG. 7(b) is a~~

FIG. 7 is a cross-sectional view showing an injection ^{taken a long section line X-X of FIG. 7(a)} plate.

~~FIGS. 8(a) and 8(b) are a front view and a side view, respectively,~~
~~FIG. 8 is a view showing an assembly of plate.~~

~~FIG. 9 is a view showing a spray pattern.~~

~~FIGS. 9(a) and 9(b) are an explanatory side view~~
~~and a graph diagram depicting the spray patterns and~~
~~flow distribution, indicative of the present invention.~~

plates applicable to the present invention

FIG. 10 is a vertical cross-sectional view showing an injection nozzle portion when a needle valve is used.

FIG. 11(a) and 11(b) are views and a thereof
~~FIG. 11 is~~ a vertical cross-sectional view showing another embodiment of an injection nozzle portion.

5

DESCRIPTION OF THE PREFERRED EMBODIMENTS

A fuel injection valve in accordance with the present invention and the fuel injection method will be described below in detail, referring to the accompanied drawings.

(i.e., FIGS. 1(a) and 1(b))
 10 FIG. 1 is a view showing the state *in which* an embodiment of a solenoid-operated fuel injection valve in accordance with the present invention is mounted onto an intake pipe of a multi-cylinder internal combustion engine, *in which* and FIG. 1 (a) is a partially sectional view showing the state.

15 Further, FIG. 1 (b) is a view showing the positional relationship between an intake valve and the solenoid-operated fuel injection valve 1 seeing from an S-direction illustrated by an arrow in FIG. 1 (a).

The reference character 101 indicates one of
 20 cylinders of the multi-cylinder internal combustion engine; the reference character 102 is a combustion chamber; the reference character 103 is an intake valve for opening and closing intake ports 104; the reference character 105 is an intake passage having a central separating wall 105a for
 25 separating the intake ports 104 and communicating the intake ports with each other in the upstream side; the reference character 106 is an intake pipe; the reference

character 107 is an intake air flow control device; the reference character 108 indicates a flow of intake air; the reference character 109 ^{(see also 109a in Fig. 1 (b))} is an inner wall surface of the intake passage 105 opposite to an inner wall surface in the side of the solenoid-operated fuel injection valve 1; and the reference character 100a is a schematic view showing sprays injected from the solenoid-operated fuel injection valve 1.

The intake air flow control device 107 has an opening-and-closing valve 110, which is rotated around a rotation shaft 110a. Two of the intake ports 104 are juxtaposed for one of the combustion chambers ¹⁰² 104, and two sprays (bi-directional spray) are injected toward individual centers of the intake ports 104. In regard to the fuel injection method, the present embodiment employs a multi-point injection (MPI) system in which each of the solenoid-operated fuel injection valves 1 is arranged in the upstream side of the intake valves 103 for each of the combustion chambers 102.

The opening-and-closing valve 110 is constructed so that the axial direction of the rotation shaft 110a is nearly parallel to a plane including two virtual center axial lines in the injection directions of the two sprays which are injected from the solenoid-operated fuel injection valve 1, and nearly perpendicular to the direction of the valve stem (or the axis of the valve or the center axis line) which agrees with the driving

direction of the valve disc of the solenoid-operated fuel injection valve 1.

Although the explanation in the present embodiment is made on the case of two intake ports 104, the present
5 embodiment may be applied to structures having three or more intake ports 104.

In order to improve the quality and the shape forming condition of the mixed gas in the cylinder, the spray 100a is required to increase the atomization degree. In addition
10 to this, in order to reduce an amount of fuel attaching onto the inner wall surfaces of the intake pipe 106 and the intake passage 105, the directivity and the shape of the spray ~~pad~~ ^{and} further ^{the} injection timing are optimized. The intake air flow control device 107 generates a tumble flow
15 by narrowing the passage area of the intake pipe 106 at closing time to increase speed of the intake air flow.

Each of the fuel sprays injected from the solenoid-operated fuel injection valve 1 is produced so as to be directed to the disc portion 103a or 103b of the intake
20 valves 103 with a narrow injection angle capable of avoiding ~~to attach~~ ^{attaching} onto the passage walls of the intake pipe 106 and the intake passage 105 and further onto the central separating wall 105a. That is, the spray 100a is of a hollow cone shape in which the density of the spray is thin
25 in the central portion and dense in the outer portion, and is uniformly distributed on the surface of the disc portion 103a of the intake valve body 103. The bi-directional

conical well- atomized sprays are formed to suppress attaching of the spray onto the walls.

A combustion test using an internal combustion engine was conducted, and it was confirmed that the exhaust gas performance and the fuel consumption performance were improved, and that by the solenoid-operated fuel injection valve 1 described above, the attaching of fuel onto the inner wall surface of the intake pipe was suppressed, and the quality and the shape forming condition of the mixed gas were improved.

FIG. 2 is a view showing the present embodiment of the solenoid-operated fuel injection valve which is mounted on an intake pipe of a multi-cylinder internal combustion engine of a different type.

Similarly, the reference character 120 indicates one of cylinders of the multi-cylinder internal combustion engine; the reference character 121 is a combustion chamber; the reference character 122 is an intake valve for opening and closing intake ports 123; the reference character 124 is a cylinder; the reference character 125 is a piston; and the reference character 126 is a spark plug. Further, the reference character 127 is an intake passage; the reference character 128 is an intake pipe; the reference character 129 is an intake air flow control device; the reference character 130 indicates a flow of intake air, and the intake air flow control device has an opening-and-closing valve 131. Two of the intake ports 123

are juxtaposed, and in the case of the present embodiment, the sprays are injected toward these intake ports. In the present embodiment, the multi-point injection (MPI) system is also formed.

5 The multi-cylinder internal combustion engine is characterized ⁱⁿ by that ~~arranging~~ a plate 132 for dividing the intake passage 127 is arranged within a spray flowing zone downstream of the intake air flow control device¹²⁹, and high speed flow of intake air is generated by the dividing
10 plate 132. A purpose of arranging the dividing plate is that the transport lag is solved while mixing of air with atomized spray is being accelerated, and the quality and the shape forming condition of the mixed gas in the cylinder are improved by optimizing the injection timing.

15 Similarly to the embodiment of FIG. 1, the fuel spray injected from the solenoid-operated fuel injection valve 1 is formed so as to avoid ~~to~~ attaching onto the inner wall surface of the intake pipe 128 and ^{to be directed} ~~direct~~ to the disk portion 122a of the intake valve 122. That is, the spray is
20 of a hollow cone shape in which the density of the spray is thin in the central portion and dense in the outer portion, and is uniformly distributed on the surface of the disc portion 122a of the intake valve 122.

FIG. 3 is a schematic view showing a state in which
25 an embodiment of a solenoid-operated fuel injection valve having a different spray form is mounted on a multi-cylinder internal combustion engine of the same kind as

that in FIG. 1, seeing from the upper side of the engine.

Similarly, the reference character 140 indicates one of cylinders of the multi-cylinder internal combustion engine; the reference character 141 is a combustion chamber; the reference character 142 is an intake valve; the reference character 143 is a central separating wall; the reference character 144 is a spark plug; and the reference character 145 is an exhaust valve. On the other hand, the reference character ~~1246~~¹⁴⁶ is an intake passage; and the reference character 147 is a intake air flow control device. The reference characters 148 and 149 indicate flows of intake air, and the intake air flow control device 147 is arranged so that speed of the airflow in one side is increased when the opening-and-closing valve 147a of the intake air flow control device 147 is tilted toward one side.

The intake air flow control device 147 is constructed so that the axial direction of the rotation shaft 147 of the opening-and-closing valve 147a may be pointed toward the wall forming the intake passage 146 in the mounting side of the solenoid-operated fuel injection valve 1. Otherwise, the intake air flow control device 147 is constructed so that the valve shaft (or the valve axis or the central axis line) agreeing with a driven direction of the valve disc of the solenoid-operated fuel injection valve 1 and the rotation shaft 147b are on the same plane. Otherwise, the intake air flow control device 147 is

constructed so that the axial direction of the rotation shaft 147a is nearly parallel to a plane including two virtual center axial lines of the injection directions of the two sprays which are injected from the solenoid-operated fuel injection valve 1. The solenoid-operated fuel injection valve 1 injects fuel so that one fuel spray between the two fuel sprays is directed ^{to} one side of a plane including the rotation shaft 147b and the valve stem of the solenoid-operated fuel injection valve 1 as a boundary, and the other fuel spray between the two fuel sprays is directed ^{to} the other side of the plane as the boundary. Further, the intake air flow control device 147 is arranged so that air flow rates individually supplied to the two fuel sprays 150 and 151 injected in two directions from the solenoid-operated fuel injection valve 1 may be varied.

In FIG. 3, the intake air flow 148 flows at a high speed, and the intake air flow 149 flows at a low speed. The two intake valves 142 are juxtaposed, and in the present embodiment, the sprays are also injected toward the intake valves. In the present embodiment, each of the solenoid-operated fuel injection valves 1 is arranged in the upstream side of the intake valves 142 for each of the combustion chambers, and the multi-point injection (MPI) system is also formed.

The present embodiment is characterized by the shape of the fuel spray injected from the solenoid-operated fuel injection valve 1. Although a detailed technique in regard

to forming the spray is to be described later, a well-atomized hollow spray having a weak penetration is formed in the high speed intake air flow 148 side of the intake passage 146, and a hollow spray having a strong penetration
 5 is formed in the low speed intake air flow 149 side. As described above, by optimizing the air flow and the spray form, the transport lag of the fuel spray is solved, and the quality of the mixed gas (stratification of the mixed gas) produced in the combustion chamber ¹⁴¹~~142~~ is improved to
 10 stabilize the combustion.

A combustion test using an internal combustion engine was conducted, and it was confirmed that the ignitability was good, and the stable combustion zone was expanded
 toward ^alean burning side, and the exhaust gas performance
 15 and the fuel consumption performance were improved.

Description will be made below on the structure and the operation of the fuel injection valve 1 capable of the above-described spray, referring to FIG. 4 to FIG. 8.

FIG. 4 is a vertical cross-sectional view showing a
 20 solenoid-operated fuel injection valve 1 in accordance with the present invention. The structure and the operation will be described below.

The solenoid-operated fuel injection valve 1 inject^s fuel by opening and closing the valve seat portion according to ON-OFF signals of ^{a cycle}duty calculated by a control
 25 unit.

The magnetic circuit is comprised of a nearly

cylindrical tube 2 ^{which} serves as a core, the cylindrical tube 2
 having a fuel introduction portion in one opening end 2a
 and an opening end 2b; a tube-shaped piece 3 having a
 function as a yoke, a part of the tube-shaped piece 3 being
 5 fixed to a ^{thin-walled} ~~thin-thickness~~ cylindrical member 7 one end of
 which is inserted over and fixed to an outer peripheral
 portion near the opening portion 2b of the cylindrical tube
 2, the tube-shaped piece 2 being made of a ferromagnetic
 material and formed so as to at least partially surround a
 10 solenoid coil 5; a plug part 4 for closing one end of the
 tube-shaped piece 3; and a cylindrical anchor 6, the
 cylindrical anchor 6 being arranged opposite to ^{an} ~~a~~ end
 surface of the opening end 2b of the cylindrical tube 2
 acting as the core through a gap.

15 A valve body 10 is comprised of a rod 8 arranged on
 the inner peripheral surface of the anchor 6, the rod 8
 being formed by rolling round a plate member having a
 partially opened portion 8a; and a ball 9 fixed to the
 other opening end portion of the rod 8 by welding. The
 20 valve body 10 is guided by the anchor 6 and the outer
 peripheral portion of the ball 9. A plurality of cut
 surfaces 9a for making fuel pass through are formed in the
 ball 9. The ball 9 is in contact with a valve seat surface
 12 formed in a valve seat member 11. A guide surface for
 25 guiding the ball 9 is formed on the inner radial portion of
 the valve seat member 11. *The above details are illustrated in Fig. 5,*
 The valve seat member 11 is press-inserted into an

inner peripheral surface 7a of one end of the ~~thin-~~
^{thin-walled}
~~thickness~~ cylinder member 7 made of a non-magnetic material
 or a weak magnetic material, and a plate with fuel swirl
 mechanisms having a function of atomization and a plate
 5 with holes (through holes) having a shape (including the
 size) required for controlling the injection direction and
 the spray pattern are press-inserted into and fixed to the
 further downstream portion of the ~~thin-thickness~~
^{thin-walled}
 member 7. The plate with the fuel swirl mechanism is formed
 10 of a fuel-in plate 13 and a swirl plate 14, and the plate
 with holes for controlling the injection direction and the
 spray pattern is formed of an injection plate 15. In the
 present embodiment, the fuel-in plate 13, the swirl plate
 14 and the injection plate 15 are press-inserted into and
 15 fixed to the ~~thin-thickness~~
^{thin-walled}
 cylinder member 7 in the
 downstream side of the valve seat member 11 in this order
 from the upstream side.

Each of the plates described above is a plate member
 of which a dimension in the thickness direction (a
 20 dimension in the direction of the valve axis in the
 condition the plate is assembled in the solenoid-operated
 fuel injection valve 1) is a very small value compared to a
 dimension in a direction (a dimension in the radial
 direction) intersecting with the thickness direction at
 25 right angle.

The reference character 16 is a welded portion
 through laser welding. In this case, the welded portion

corresponds to the outer periphery of the injection plate 15, the welded portion prevents fuel from leaking to the outside.

When the valve seat member 11, the fuel-in plate 13, the swirl plate 14 and the injection plate 16 are inserted into and fixed to the ~~thin-thickness~~ ^{thin-walled} cylinder member 7, the gap between the end surface of the anchor 6 of the valve body 10 and the end surface of the opening end 2b of the ~~tube-chapped tube~~ ^{tube-shaped piece} 3 acting as the core is adjusted. That is, the gap is formed as a moving distance of the valve body 10 in the axial direction. Further, the valve body 10 is pushed to the valve seat surface 12 of the valve seat member 11 by a return spring 17, and the pressing force is adjusted by an axial position of a rolled bushing 18 formed by rolling a plate material in a roll-shape.

Further, in the present embodiment, the bottom end surface of the cylindrical tube 2 acting as the core serves as a stopper for receiving the anchor 6 at valve opening operation. Therefore, it is preferable that the bottom end surface of the cylindrical tube 2 and the top end surface of the anchor 6 are plated with chromium or the like through electroplating or the like.

A coil 5 for energizing the magnetic circuit is wound around a bobbin 19. Terminals 21 of the coil are connected to terminals of the control unit, not shown.

The outer peripheries of the cylindrical tube 2 acting as the core and the tube-shaped piece 3 having the

function of the yoke are surrounded with a plastic mold 20 formed through injection molding. In this case, the coil terminals 21 are molded together in a one-piece structure. Further, an O-ring 23 for sealing fuel is arranged between one end surface 20a of the plastic mold 20 and a bushing 22 inserted into and fixed to the end portion 7a of the cylinder member 7. Further, an O-ring 24 for sealing fuel is arranged in the side of the other end 20b. Therein, the reference character 25 is a filter which is arranged in order to prevent particles or extraneous objects contained in the fuel from entering between the ball 9 and the valve seat surface 12, that is, what is called the valve seat side of the valve.

The operation of the solenoid-operated fuel injection valve 1 constructed as described above will be described below.

The valve body 10 is vertically moved in the axial direction to open and close the gap between the ball 9 and the valve seat surface 12 according to an electric ON-OFF signal applied to the solenoid coil 5, and thereby fuel injection control is performed. As the electric signal is applied to the coil 5, the magnetic circuit is formed by the cylindrical tube 2 acting as the core, the tube-shaped piece 3 having the function of yoke and the anchor 6, and the anchor 6 is attracted toward the side of the cylindrical tube 2. As the anchor 6 is moved, the ball 9 united with the anchor 6 is also moved to be detached from

the valve seat surface 12 of the valve seat member 11 and to release the fuel passage in the upstream side of the fuel-in plate 13.

Fuel flows inside of the solenoid-operated fuel injection valve 1 through the filter 25, and flows downstream through the inside of the anchor 6 and the opening portion of the rod 8 linked to the anchor 6, and further flows from the valve seat surface 12 of the valve seat member 11 to the outer peripheral portion of the fuel-in plate 13, and the fuel is added with a swirl force by the swirl plate 14 and injected through the injection plate 15.

Here, the structures of the fuel-in plate 13, the swirl plate 14 and the injection plate 15 will be described, referring to FIG. 6 to FIG. 8.

FIGS. 6(a), 6(b) and 6(c) are
~~FIG. 6 is~~ front views showing each of the plates. FIG. 6 (a) shows the fuel-in plate 13 which has D-cut surface ^s 13a ~~and 13b~~. The D-cut surfaces 13a ~~and 13b~~ form passage wall surfaces of fuel passages communicating the upstream side end surface of the fuel-in plate 13 with the downstream side end surface. FIG. 6 (b) shows the swirl plate 14. The swirl plate 14 comprises two through holes (swirl chambers 14a) penetrating from the upstream side end surface to the downstream side end surface, the through holes 14a being independently juxtaposed in the surface direction of both of the upstream side end surface and the downstream side end surface; and fuel passages ~~8~~ (offset

passages 14b) ^{are through} provided each of the swirl chamber 14a, the fuel passage 14b communicating with the swirl chamber so as to be directed in a direction offset to the center of the swirl chamber 14a. The swirl chamber 14a is formed so that the section perpendicular to the valve axis is circular. In this embodiment, a pair (two) of the offset passages 14b are provided for each of the swirl chambers 14a, and the offset passage 14b is connected to the swirl chamber 14a in the tangential direction. The offset passage 14b composes a fuel passage as a swirl force adding means for adding a swirl force to the fuel passing through there. The swirl chamber 14a may be included in the swirl force adding means. FIG. 6 (c) shows the injection plate 15. The injection plate 15 comprises two fuel injection holes 15a comprised of two through 15a holes independently juxtaposed in the surface direction of both of the upstream side end surface and the downstream side end surface, and the two fuel injection holes 15a penetrate from the upstream side end surface to the downstream side end surface so as to direct directions different from each other. Each of the two fuel injection holes 15a is formed at a position corresponding to the center of each of the swirl chambers 14a. These plates 13, 14 and 15 are formed of a thin plate metallic material (0.08 mm to 0.5 mm in), and a large amount of the plates can be manufactured without deviation because stamping work and etching work or the like may be used for forming the plates.

The D-cut surface 13a of axial direction passage provided in the fuel-in plate 13 has a function forming the fuel passage, and accordingly the fuel passage may be formed ^{as} a through hole in the valve axial direction at a position corresponding to the offset passage 14b in the downstream side.

FIGS. 7(a)-7(b) illustrate
~~FIG. 7 shows an example of the structure of the fuel injection holes 15a formed in the injection plate 15,~~ *in which*
~~FIG. 7(b) is a cross-sectional view along section line X-X of FIG. 7(a) which shows the X-X section of FIG. 6(c). The center lines of~~ *and*
 10 the two fuel injection holes 15a are tilted by 5° to 10° *which corresponds to that*
 so that the interval between the two center lines becomes wider toward the downstream side, and the angle between the center lines θ is set within such an angle that the centers of sprays individually ~~direct~~ *are directed* to central positions
 15 of the intake valves in an internal combustion engine of a two-intake valve type to be described later.

FIGS. 8(a)-8(c) illustrate
~~FIG. 8 shows~~ a state of the spray generating means constructed by assembling the fuel-in plate 13, the swirl plate 14 and the injection plate 15. FIG. 8 (a) is the
 20 front view seeing from the upstream side in the direction of the valve axis, and FIG. 8 (b) is the side view seeing from the direction of an arrow b in FIG. 8 (a). Although the assembling work is performed when the plates are assembled in the injection valve 1, as described above, the
 25 spray generating means may be assembled in advance by bonding the plates as shown in the figure. Therein, the fuel-in plate 13 and the swirl plate 14 may be formed of a

non-metallic material, and the function can be satisfied even in such a case.

The fuel passage will be described below. Fuel flows from the upper side toward the offset passages 14b exposed from the ^{D-cut}~~D-cur~~ surfaces 13a of the fuel-in plate 13, and then flows into the swirl chambers 14a communicating the pairs of the offset passages 14b. At that time, the fuel is added with a swirl force. The swirling fuel flows down to the fuel injection holes 15a positioned under the centers of the swirl chambers to be injected outside the fuel injection valve 1.

FIG. 9 shows a form of the injected spray. The spray is made bi-directional. The illustrated case is that swirl intensities of the fuel for forming the sprays are designed so as to be equal to each other. The spray 100a is of a hollow cone shape in which the density of the spray is thin in the central portion and dense in the outer (peripheral) portion. FIG. 9 (b) shows the flow distribution measured by a trapping pan method. The flow distribution is nearly symmetric with respect to the center O of flow rate. The angle θ s geometrically calculated from the distance between the center O of flow rate and the central axis of the solenoid-operated fuel injection valve 1 and the length L of the perpendicular drawn from the top end portion of the solenoid-operated fuel injection valve 1 down to the segment Y-Y connecting the centers of the two intake ports 104 is equivalent to the angle θ_h of FIG. 7. The sprays

100a are distributed uniformly on the surfaces of the disc portions 103a, 103b of the intake valves 103 avoiding the central portions of the disc portions 103a, 103b. The spray angle θ_s is set to a value 10° to 20° . That is, the spray angle θ_s is set to a value equal to or smaller than the center angle of the intake valves in the internal combustion engine of a two intake valve type. The reason why the angle is set as described above is that it is found that the droplets of the spray are dragged outward by intake air flow, that is, dragged toward the inner wall surface 109a side of the intake pipe.

In order to make the penetration different between the two sprays 150 and 151, as shown in FIG. 3, the intensities of the swirled fuel produced by the swirl plate 14 are made different from each other. In detail, this can be attained by adjusting the sectional area of the passage or the amount of offset of the offset passage 14b. The penetration becomes strong when the offset amount is decreased, and the penetration becomes weak when the passage sectional area is decreased.

In the structure ^{of} ~~if~~ the embodiment of the solenoid-operated fuel injection valve 1 shown in FIG. 1 to FIG. 3, the following considerations are taken, and the following features are obtained.

- (1) Improvement of atomization of the injected fuel is performed by adding the swirl force to the fuel using the swirl plate 14. The fuel introduced from the upper side

(upstream side) flows to the offset passage 14b which is offset with respect to the central axis of the swirl plate 14, and is added with the swirl force by the offset passage 14b to flow into the swirl chamber 14a. Since the flow path from the axial direction passage 13a formed on the fuel-in plate arranged upstream to the swirl chamber 14a forms a loss-less flow passage allowing a desired amount of fuel to flow, the pressure energy is effectively converted to the swirling energy to accelerate the atomization when the fuel is injected through the fuel injection hole 15a formed in the injection plate 15.

(2) The control of spray direction is performed by the injection plate 15. The two tilted fuel injection holes 15a and 15b are provided in the injection plate 15. In the case of each of the embodiment described above, the injection directions are bi-directional, and are controlled so as to be directed onto the intake valves. The fuel injection holes 15a are positioned under (in the downstream of) the centers of the swirl chambers 14a formed in the swirl plate 14 in the upstream side to effectively inject the swirling fuel. The tilted angle of the fuel injection hole 15a is formed in 5° to 10° so as to avoid interference between the two sprays.

(3) The adjustment of the injected amount is performed by accurately manufacturing the ~~thin-thickness~~ plates 13, 14 and 15 *so that each has a very thin thickness* compared to the diameter. That is, the D-cut surface 13a formed in the

fuel-in plate 13, the swirl chamber 14a formed in the swirl plate 14 and the fuel injection hole 15a formed in the injection plate 15 are manufactured through the press-stamping work, the etching work or the like, and the plates
5 are assembled in the injection valve 1. At assembling the plates, no large unbalanced load is applied to the fuel-in plate 13 and the swirl plate 14 because the assembling load is applied through the injection plate 15. Although the outer periphery 16 of the injection plate 15 is fixed by
10 laser welding or the like, the fuel injection holes 15a are hardly influenced by the thermal deformation because the holes are distant from the welded fixed portion.

(4) The very thin plate material is used for the fuel-in plate 13 and the injection plate 15. Since the thickness is,
15 for example, 0.1 mm to 0.3 mm, the workability is very easy, and accordingly, the plates can be manufactured through the press-stamping work, the etching work or the like. Therefore, the deviations in the dimension and the shape can be made very small even the plates are massively
20 manufactured. Further, the plates can be economically manufactured due to the mass-production.

Furthermore, different kinds of materials (for example, a non-metallic material etc.) having good workability may be used for the fuel-in plate 13 and the
25 swirl plate 14, and thereby the productivity can be further improved.

By forming the fuel-in plate 13, the swirl plate 14

and the injection plate 15 in a unit as shown in FIG. 8, assembling of the plates to the main body of the fuel injection valve can be easily performed. By doing so, handling of the parts in a manufacturing line becomes easy, and in the viewpoint of prevention of attaching of extraneous objects after working and the dimension control, the handling also becomes easy. Particularly, there is an advantage in cost because quality control can be performed at the part level¹ and² accordingly, it is unnecessary to dispose off-specification products of the fuel injection valve body themselves.

The other embodiments of solenoid-operated fuel injection valves will be described below, referring to FIG. 10 and FIG. 11.

Instead of the ball valve in FIG. 1 to FIG. 3, a needle valve 30 may be used for the valve body, as shown in FIG. 10.

In the present embodiment, fuel flows around the valve body, and is supplied to the contact portion between a valve seat surface 12 and the needle valve 30 from a vertical passage 34 of an anchor 33 through a fuel passage portion 31 provided in a valve body guide portion 32. In this structure, the same operations and the same effects as those in the embodiment of FIG. 1 to FIG. 3 can be also attained.

FIG. 11(a) is a vertical sectional view showing the valve top end portion of a solenoid-operated fuel injection

valve having an injection plate 41 which has a plurality of small holes as a different method of generating a spray form. ~~[In the figure,]~~ FIG. 11 (b) is a view seeing from the direction shown by an arrow Z in FIG. 11 (a). When the ball 9 is driven and detached from the valve seat surface 12 to release the fuel passage in the upstream side of a fuel-in plate 40, fuel flows from the valve seat surface 12 to an injection plate 41 through vertical holes 40a ~~[and 40b]~~ of the fuel-in plate 40. There, the fuel is injected through the plurality of small holes 42, 43 formed in the injection plate 41. In this case, since number of the small holes 42 and number of the small holes 43 are different from each other, the forms of the injected sprays are accordingly different from each other. That is, the penetration of the spray injected from the small holes 42 is strong, and the penetration of the spray injected from the small holes 43 is weak. The spray form of this kind is suitable for the internal combustion engine shown in FIG. 3. In this structure, the same operations and the same effects as those in the embodiment of FIG. 1 to FIG. 3 can be also attained. The present embodiment has an advantage in that various kinds of spray forms can be obtained by varying the diameter and number of the holes, ^{and} the angle of the holes.

According to the present invention, atomization of fuel injected toward two directions can be improved by arranging the swirl force adding means for adding a swirl force to the fuel in the upstream side of the fuel

injection holes and in the downstream side of the valve seat corresponding to each of the fuel injection holes.

Further, the time lag in the traveling time until the spray reaches to the combustion chamber between the two
5 fuel sprays can be solved by providing a means for making the penetration different between the fuel sprays injected toward two directions.